Co-Optimization of Vehicles and Routes (CoVaR)

To Improve Commercial Transportation System Efficiency

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PACCAR Inc.
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Project ID eems108

Overview

Timeline:

- Start: October 2020
- End: December 2023
- 50% Complete

Budget:

- Total project funding: $2.5M
  - DOE: $2M
  - Cost Share: $0.5M
- FY2021 Funding: $1.2M
- FY2022 Funding: $0.79M

Barriers:

- Business Incentives for Cloud-Providers, OEMs, and Fleets
- Vehicle to Cloud Architecture Technologies
- Network Bandwidth

Partners:

Relevance

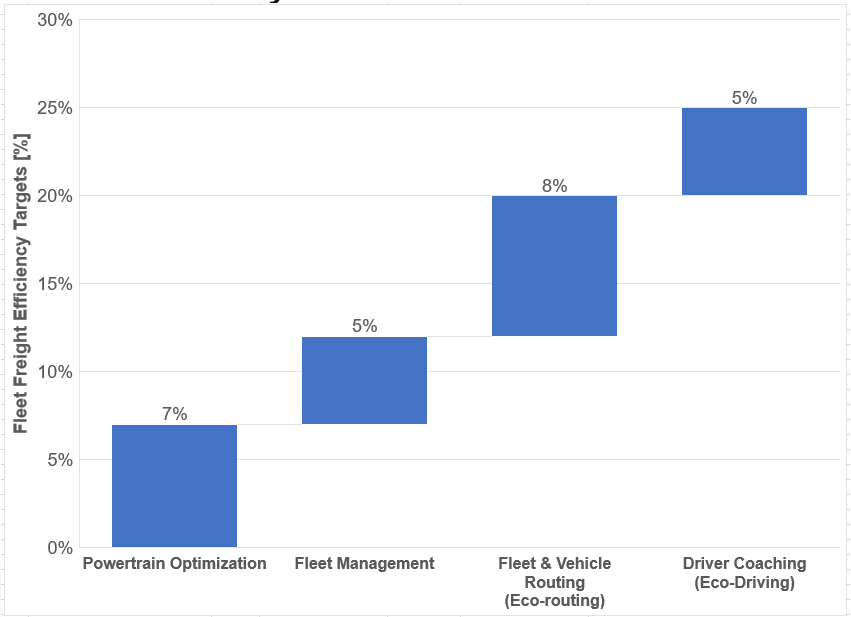
Objectives:

- 25% Fleet Freight Efficiency Improvement
- Develop, Implement, & Validate Advanced Connected Transportation Systems
- Powertrain Agnostic:

  Diesel and e-Powertrain

Impact:

- Improve Fleet Freight Efficiency Through Various Connectivity Systems:



Program Outline

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		2020	2021				2022				2023			
Task		Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4
Fleet Partner Selection														
Telematics														
	Development													
Eco-Routing														
	Development													
	Integration													
	Simulated Impact Assessment													
Powertrain Recommendation														
	Development													
	BEV Model Development													
	Simulated Impact Assessment													
Fleet Management System														
	Development													
	Integration													
	Simulated Impact Assessment													
Cloud Infrastructure	Development													
Deployment														
	Deploy Telematics Loggers													
	Deploy Eco-Routing													
	Deploy FMS													
	Deploy Powertrain Recommendation													
Data Analysis	Energy Efficiency Assessment													

Budget Period 1: Technology Development

Budget Period 2: Technology Implementation

Budget Period 3: Testing & Validation

Milestones

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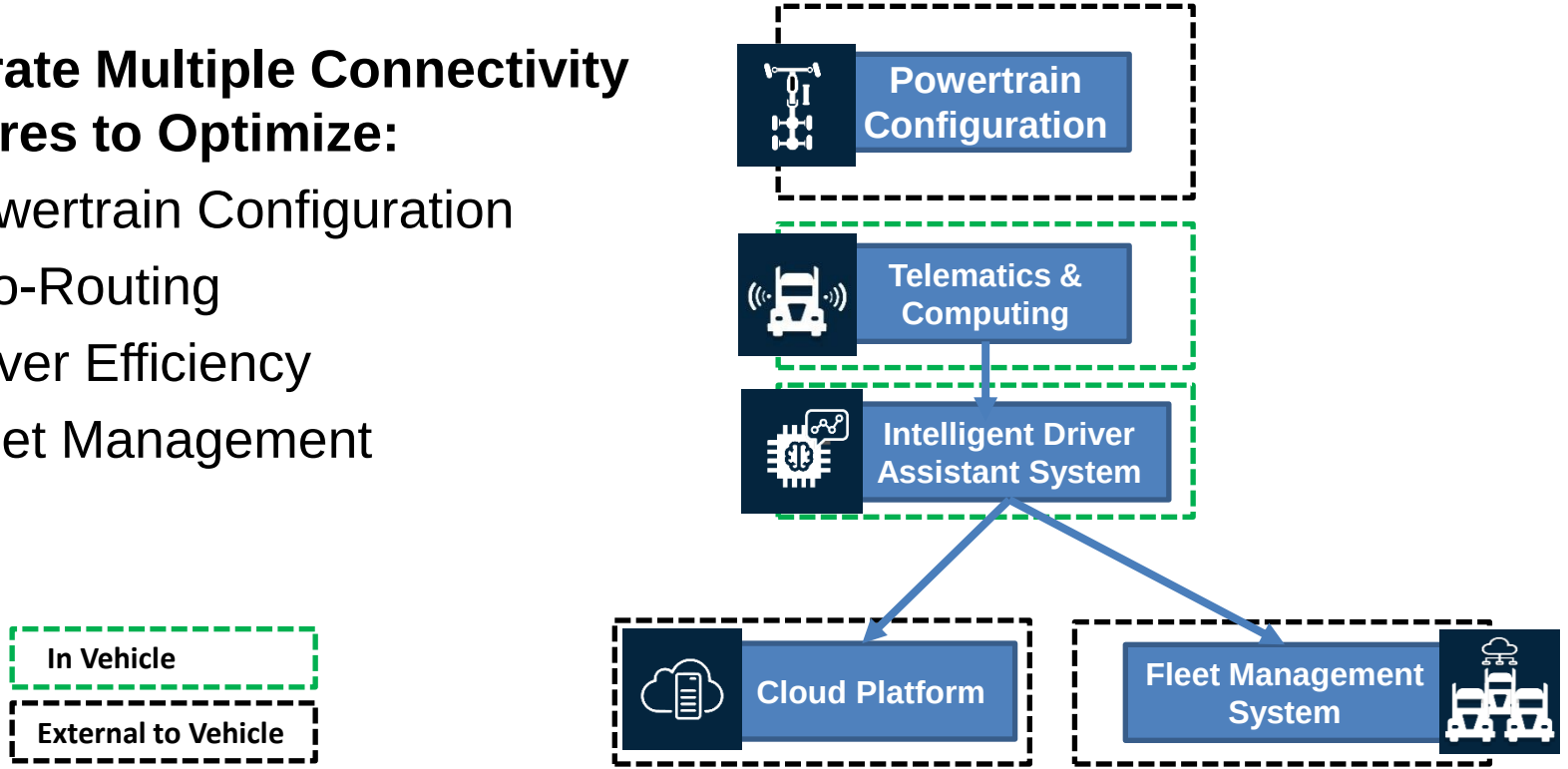
Milestone	Description	Status
Baseline Freight Energy Efficiency Quantified	Number of Current Freight Energy Efficiency in Appropriate Units	In-Progress
Selection of Fleet Partner	Determine fleet partner for field test	Complete
Intelligent Driver Assistance System (IDAS) Assessment	Assessment of IDAS Ability to Meet Freight Efficiency Target	Complete
Fleet Management System (FMS) Assessment	Assessment of FMS Ability to Meet the Freight Efficiency Target	Complete
Vehicle Configuration Optimization System Assessment	Assessment of the Vehicle Configuration Optimization System's Ability to meet the Freight Efficiency Target.	Complete
Baseline Testing on Commercial Fleet	Simulation to Determine if Freight Efficiency Improvement is achievable	In-Progress
Deploy Prototype IDAS	Data and feedback collection on the IDAS with fleet partner	In-Progress
Deploy Prototype FMS	Data and feedback collection on the FMS with fleet partner	In-Progress
Vehicle Configuration Optimization Workshop	Workshop with fleet partner on potential vehicle configuration optimizations	In-Progress
Complete Testing of Prototype Technology	Complete initial prototype testing with fleet partner	In-Progress

Approach

Integrate Multiple Connectivity Features to Optimize:

- Powertrain Configuration
- Eco-Routing
- Driver Efficiency
- Fleet Management



Approach: Eco-Routing

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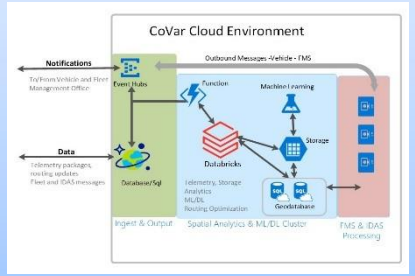
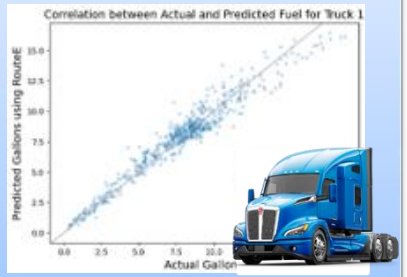
Cloud Based Data → Vehicle Model Training → Eco-Routing → Run By Turn Directions

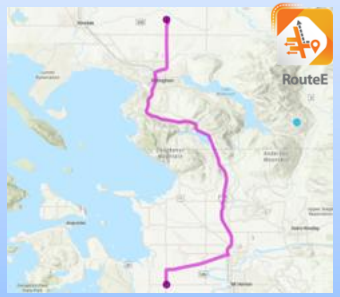
Advanced Telematics



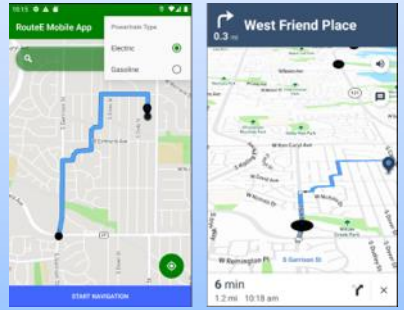
RouteE Energy Models



Routing Engine



In vehicle eco-routing



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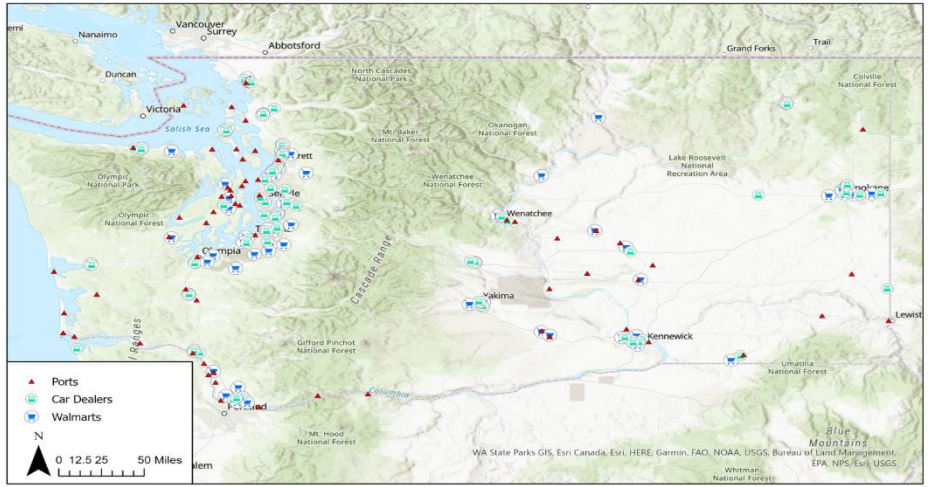
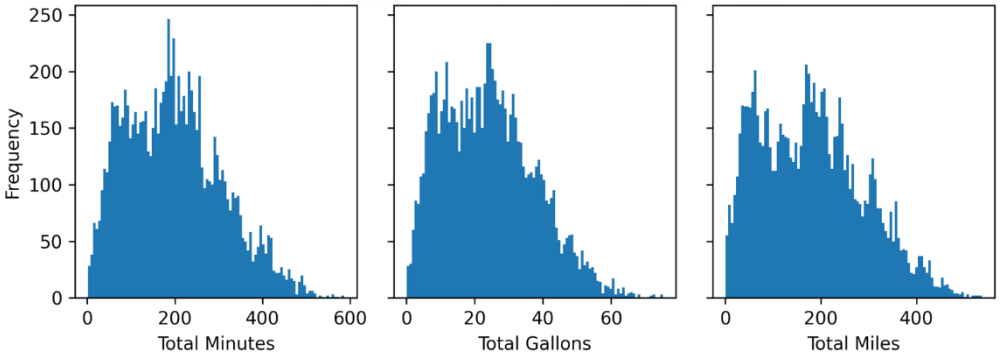
Technical Accomplishments: Routing Study

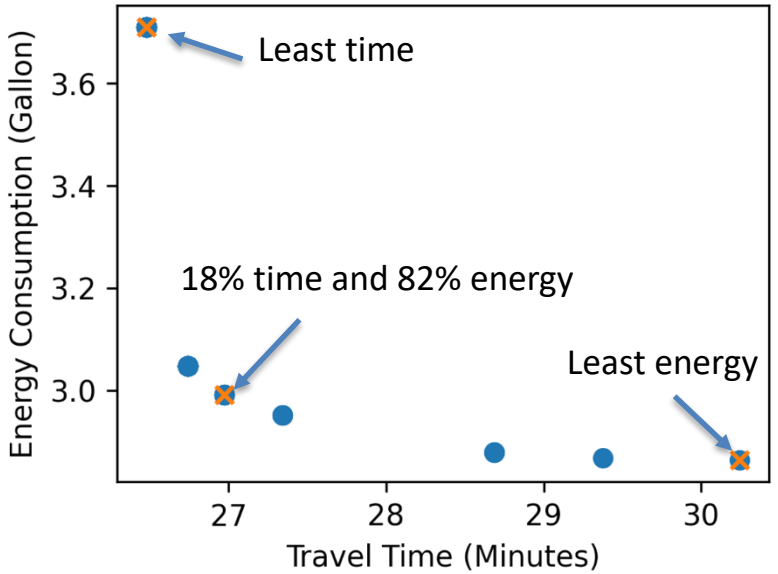
- **Objectives**
  - Exercise the eco-routing capability
  - Quantify the potential eco-routing energy savings opportunity
- **Approach**: Generate synthetic origin-destination (O/D) pairs
  - Origins: 63 ports in the Washington State
  - Destinations: 84 vehicle dealers and 66 Walmart locations
  - 9450 O-D pairs in total





Technical Accomplishments: Routing Results for One O-D Pair, Showing Discrete Options and Pareto Front

- Pareto optimal routing results with two objectives: time and energy

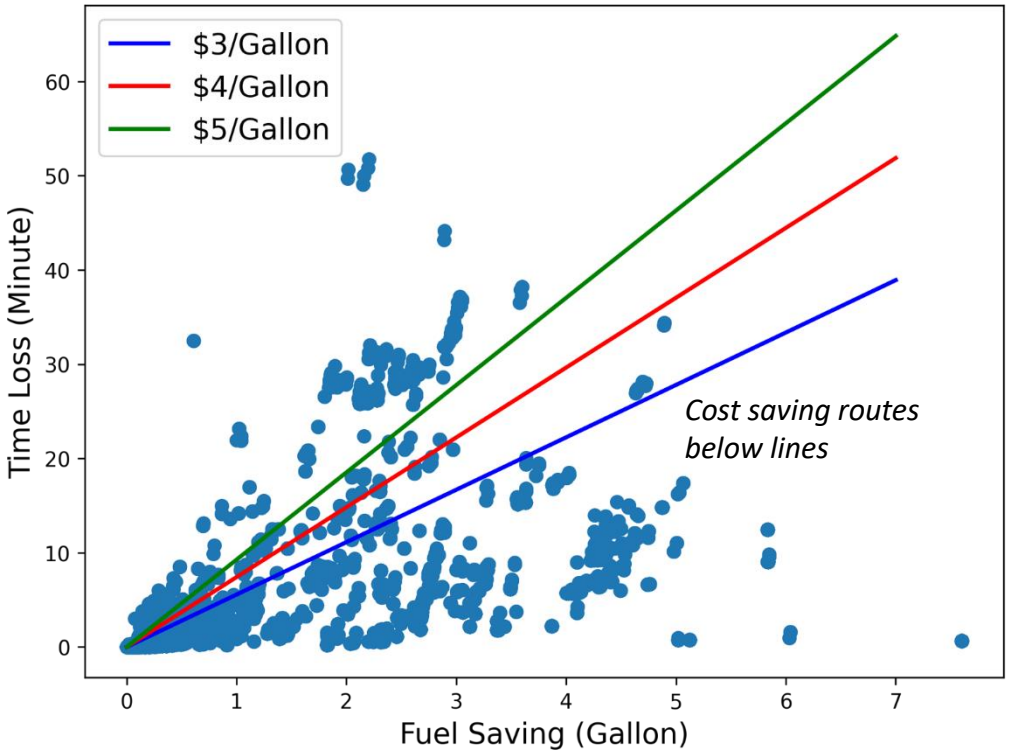


Route	Time (minutes)	Energy (gallons)	Distance (miles)
Least energy	30.2	2.8	15.8
Least time	26.4	3.7	14.6
18% time and 82% energy	26.9	2.9	14.8

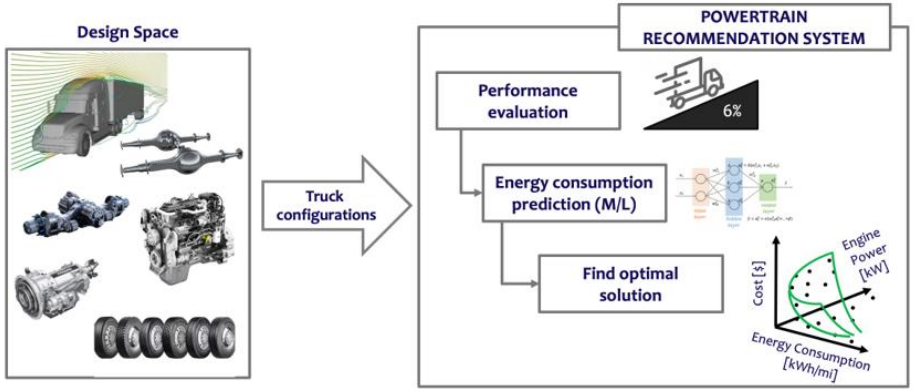
Routing Study: Economically Feasible Routes

Economically feasible routes below fuel cost curve

- Normalized comparison of time and energy differences between routes
- Labor and fuel costs can vary, current assumptions are:
  - Labor (driver): $32.37/hour (source: U.S. DOT, 2016)
  - Diesel costs of $3 to $5 per gallon

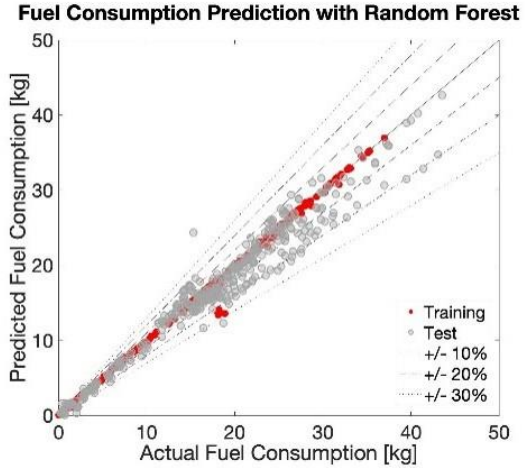


Technical Accomplishments: Powertrain Optimization



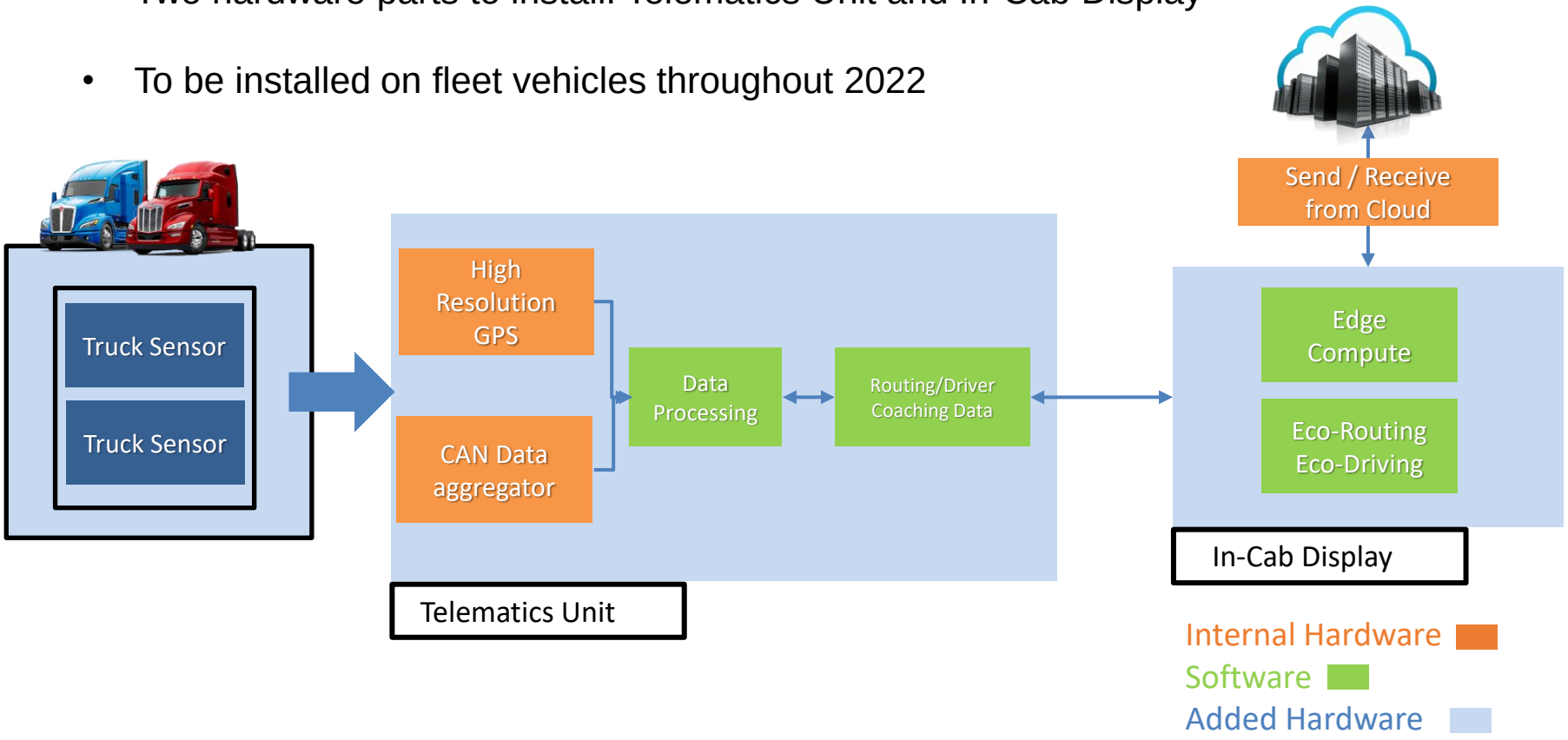
- Explore the design space to find configurations that meet customer's requirements
- Leverage real-world driving data and machine learning to predict the most energy efficient truck for a desired operation

- Machine Learning (M/L) Models (Random Forest and Neural Network) for Conventional Vehicles Trained.
- MATLAB App for Powertrain Specification Optimization Developed
- Overall freight efficiency improvement for conventional (Diesel) homogeneous vehicles was simulated to be around 2%



Technical Accomplishments: Telematics Hardware

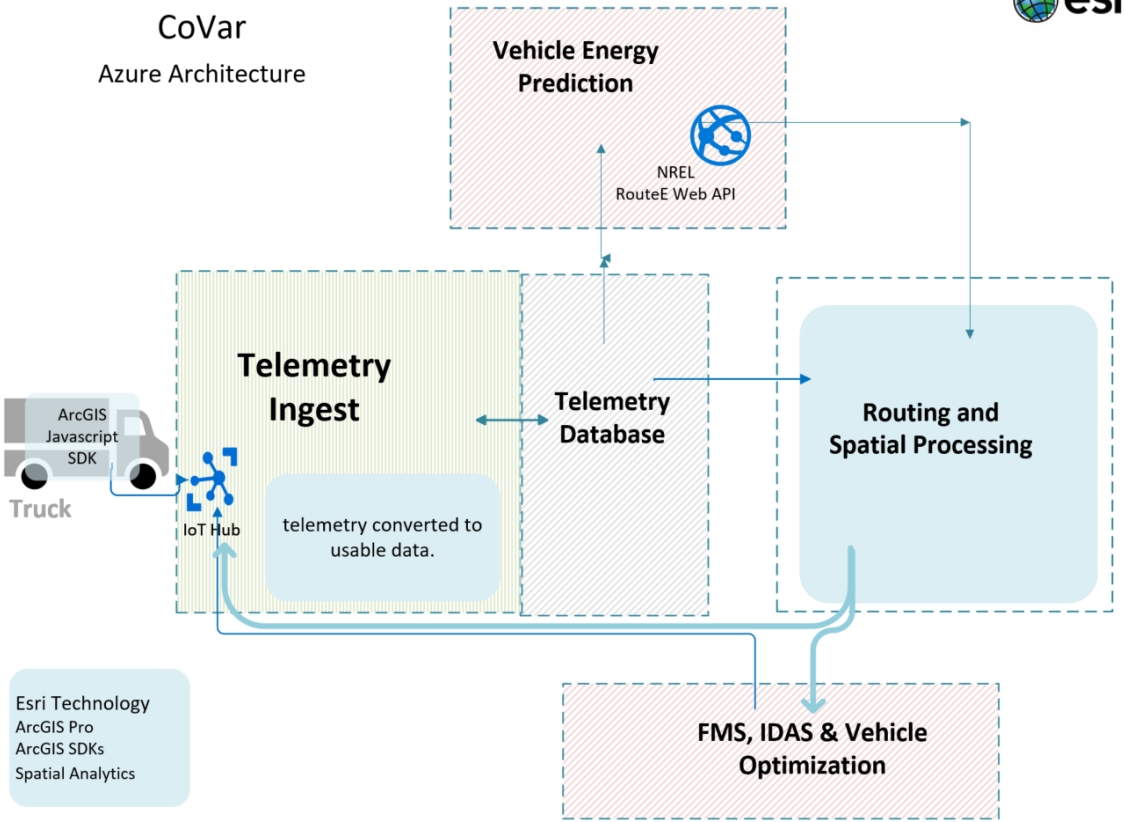
- Two hardware parts to install: Telematics Unit and In-Cab Display
- To be installed on fleet vehicles throughout 2022



Technical Accomplishments: Cloud Infrastructure

Milestones:

- Telemetry data ingest stabilized
- 1st phase ETL complete
- Long-term storage and processing available
- Ongoing testing with data from prototype test truck at PTC



Cloud Architecture Diagram for CoVaR

Technical Accomplishments
Fleet Management System

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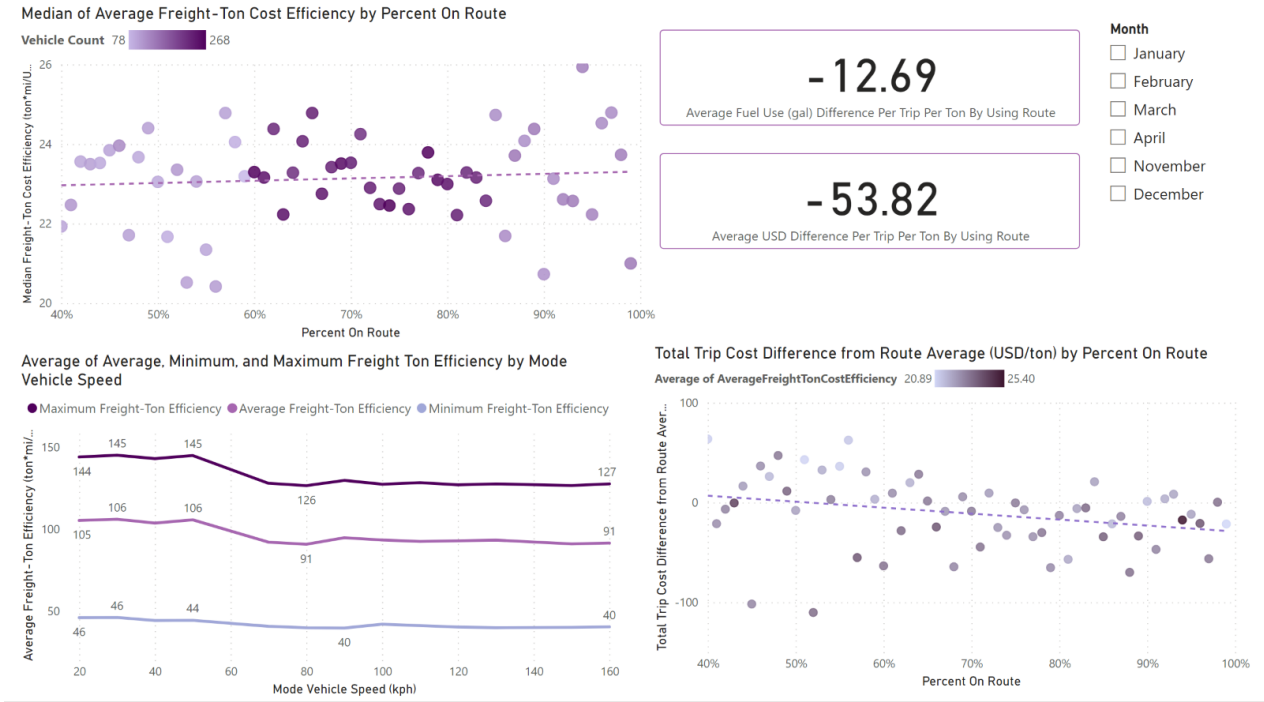
Milestones:

- Initial fleet management dashboard created based on vehicle telematics data
- Integration of Esri VRP with Eco-Routing tools in progress



Summary:

- Real-Time fleet performance monitoring and fleet energy optimized routing can be conducted with the FMS tool

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Technical Accomplishments: Intelligent Driver Assistance System

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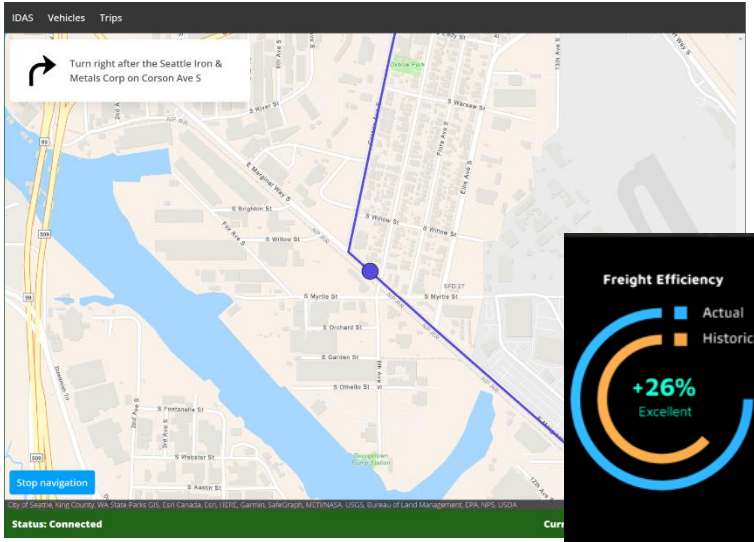
Milestones:

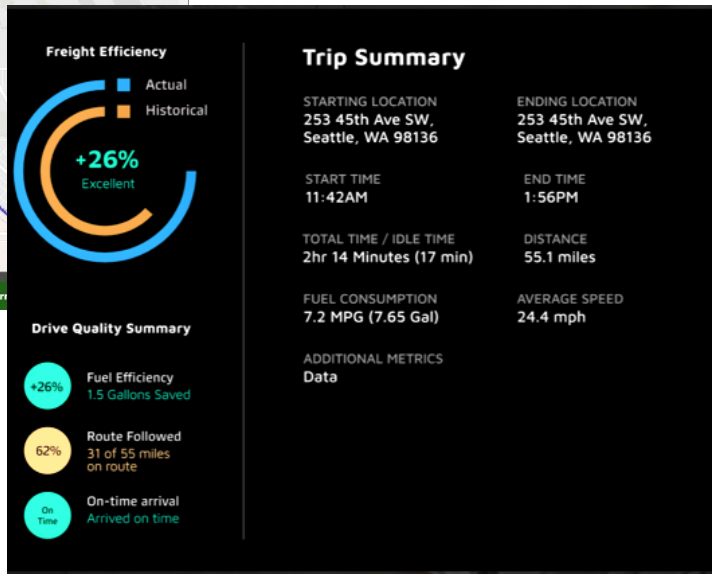
- Web App developed for easy deployment
- In-Cab routing UI functional
- Initial post-trip reporting metrics developed

Summary:

- IDAS application functional for field test



In-Cab Routing Display



Post-Trip driver report example

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Prior AMR Comments

- There are no comments from the previous review

Partnerships and Collaborations

- Kenworth: Vehicle Deployment, Fleet Partnership
- NREL: Fleet Data Analysis, Eco-Routing, Route Optimization,
- OSU: Powertrain Configuration Optimization
- Valence: Fleet Management System and IDAS
- Esri: Cloud Infrastructure and Routing

Remaining Challenges and Barriers

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Main Barriers:

- Semiconductor shortage severely limiting hardware procurement
- Integration of hardware and coordination with multiple fleets

Technical Challenges:

- Seamless Integration of Connectivity, Compute, Artificial Intelligence, and Human Machine Interaction on Vehicle
- A-B Testing of Technologies on Fleet, Engaged in Active Commercial Transportation

Proposed Future Research

FY22: Technology Implementation

- Continue Validation With Demonstrator Vehicles
- Implement Technology Package Onto Fleet Partner Vehicles
- Validate Technologies on Field Test Vehicles

FY23: Testing & Validation

- Continue testing with fleet partner
- Compare efficiency improvement with initial baseline data
- Continue model improvement based on collected data

Any Proposed Future Work is Subject to Change Based on Funding Levels.

Summary

Accomplishments:

- Fleet partner finalized
- Telematics hardware and architecture finalized
- Routing tools integrated and simulations completed
- MATLAB App for Powertrain Specification Optimization Developed

Impact:

- Potential for 25% Freight Efficiency Improvement
- Integrates Several Connectivity Technologies Which Builds Potential for Future Projects
- Powertrain Agnostic Which Makes This Technology Applicable for More Vehicles